⑫ **EUROPEAN PATENT APPLICATION**

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�54 **Suspension system for a centrifuge rotor.**

㊿ A suspension system for a rotor includes a coupling having a rigid shaft portion flexibly linked at two connection points to the rotor and to a drive spindle therefor.

FIG.1

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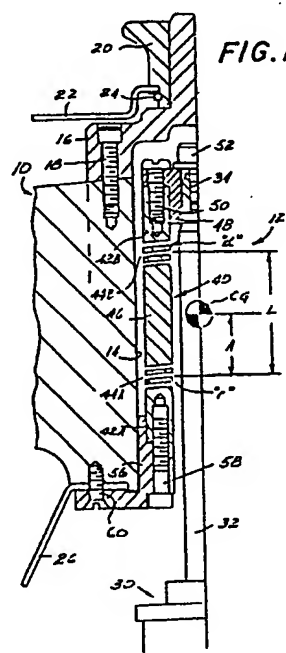
Title   IP-228-A

SUSPENSION SYSTEM FOR A CENTRIFUGE ROTOR

BACKGROUND OF THE INVENTION

Field of the Invention

5   This invention relates to a centrifuge rotor
and, in particular, to a suspension system for a
centrifuge rotor.

Description of the Prior Art

       An important consideration when using a centri-
10 fuge apparatus is insuring that the load carried by
the rotor is in balance with respect thereto. This
concern is well-founded since, as rotational speed
increases through the critical value, rotor unbalance
manifests itself as vibration. Depending upon the
15 magnitude of the unbalance, such vibration may be
sufficient to damage the centrifuge apparatus.

       For a rotating body, such as a centrifuge rotor,
to pass through its critical speed, two events must
occur simultaneously. First, the rotor's principle
20 axis, the axis through the rotor's center of gravity,
must lie parallel to the rotor's spin axis, the axis
passing through the geometric center of the rotor.
Second, the rotor's center of gravity must lie on the
spin axis. If these two events were enabled to occur
25 more quickly after rotor start-up, then the rotor
would pass through its critical speed at an earlier
time (i.e., at a lower speed) thus reducing the vibra-
tion caused by a given amount of rotor unbalance.

       In view of the foregoing it would be advanta-
30 geous to provide a centrifuge that would maintain
vibratory forces at a minimum, thus increasing the
amount of unbalance that the centrifuge would be able
to tolerate. One manner of accomplishing this end is
to reduce the critical speed of the rotor. By lower-
35 ing the rotor's critical speed, the vibration imposed

on the centrifuge by a given rotor unbalance is
commensurately reduced.

SUMMARY OF THE INVENTION

In accordance with this invention a suspension
5 system for a centrifuge rotor having a weight W is
provided which makes satisfaction of each of the two
conditions for the attainment of critical speed inde-
pendent of each other. As a result, the critical
speed of the rotor is lowered. The rotor suspension
10 system embodying the teachings of this invention com-
prises a coupling member having a first and a second
collar each flexibly connected to a rigid shaft. The
rigid shaft has a dimension L. The first collar is
flexibly connected at a first connection point "r" to
15 the centrifuge rotor while the second collar is flexi-
bly connected to the rotor drive member at a second
connection point "d". One of the flexible joints is
thus disposed a predetermined distance A from the cen-
ter of gravity of the rotor. The flexible connections
20 of the coupling exhibit predetermined torsional stiff-
ness K_d and K_r at their respective points of connec-
tion to the drive or the rotor.

In accordance with this invention the distance A
is defined by the relationship:

25

$$A = \frac{L \bullet K_r}{K_r + K_d + L \bullet W} \qquad (1)$$

where

30   K_r is the torsional stiffness at the flexible
       connection of the coupling to the rotor at
       the connection point "r";

       K_d is the torsional stiffness at the flexible
       connection of the coupling to the rotor drive
       at the connection point "d";
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A is the distance that the center of gravity of
the rotor lies from the connection point "r";

L is the length of the rigid shaft; and

W is the weight of the rotor.

5   With the suspension system of the present inven-
tion, the satisfaction of the individual conditions
necessary to make attainment of critical speed is made
independent of each other, and the rotor's critical
speed is then a function of the torsional stiffnesses
10   of the coupling, the weight W of the rotor, and the
length L of the rigid shaft.

15   BRIEF DESCRIPTION OF THE DRAWINGS

The invention may be more fully understood from
the following detailed description thereof taken in
connection with the accompanying drawings, which form
a part of this application, and in which:

20   Figure 1 is a side elevational view entirely in
section of a rotor suspension arrangement in accor-
dance with the present invention; and

Figure 2 is a force diagram illustrating the
forces acting upon the rotor suspension arrangement in
25   accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Throughout the following detailed description
similar reference numerals refer to similar elements
in all Figures of the drawings.

30   Shown in Figure 1 is a side elevational view
entirely in section of a centrifuge rotor 10 in having
a suspension system generally indicated by reference
character 12 embodying the teachings of this inven-
tion. Since the suspension system 12 may be used with
35   any well-known rotor configuration, the rotor 10 is

illustrated only fragmentally. The center of gravity of the rotor is diagrammatically indicated by the character CG. The rotor 10 has a central bore 14 with a suitable top cap 16 secured thereover as by threaded
5   bolts 18. The central projection of the top cap 16 is sized to receive a central aperture of a rotor cover knob 20. A generally disc-like rotor cover 22 is secured about the lower periphery of the knob 20 and held in position at that point by any suitable lock
10 ring 24 as well understood by those skilled in the art. The rotor 10 may be further provided with a windshield 26. The windshield 26 is fragmentally indicated in the drawings and is conveniently secured to the rotor 10 in a manner to be discussed herein.
15   Motive force for the rotor is derived from a rotor drive arrangement 30 which includes a drive spindle 32 projecting upwardly into the central bore 14. The upper end of the drive spindle 32 is provided with a threaded recess 34 for a purpose described
20 herein.
      The suspension system 12 in accordance with the present invention includes a substantially annular coupling member generally indicated by the reference character 40. The coupling member includes first and
25 second collar portions 42A and 42B, respectively. The collars are flexibly connected through suitable flexible links 44A and 44B to each end of a substantially rigid shaft portion 46. The shaft 46 has a length L while the center of gravity CG of the rotor 10 lies a
30 distance A from one of the flexible links 44. The flexible links 44A and 44B have torsional stiffnesses K_r and K_d respectively associated therewith.
      In practice the collars, flexible links, and rigid shaft are fabricated as a unitary member such as
35 that provided by Heli-cal[TM] rotating shaft flexible

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couplings such as those sold by Heli-cal Products
Company, Inc. Although such flexible couplings are
preferred, any other flexible shaft coupling may be
utilized.

5   The collar 42B is secured to a drive adapter 48
by a threaded bolt 50. The drive adapter 48 is itself
secured at the upper end of the drive spindle 32 by a
capped bolt 52 which is received within the threaded
recess 34 of the spindle 32. Similarly, the collar
10 42A is connected to a ring 56 by a threaded bolt 58.
The ring 56 is itself secured to the rotor by a
threaded bolt 60. The bolt 60 extends through the
outward portion of the ring 56 and serves to secure
not only the ring 56 but also the central portion of
15 the windshield 26 to the under surface of the rotor 10.

As may be better understood by reference to the
force diagram shown in Figure 2, the above-described
suspension system serves to suspend the rotor 10 to
the drive spindle 32 at two substantially flexible
20 connection points indicated in the drawings as connec-
tion points "r" and "d". As seen with reference to
Figure 1, connection point "r" is that flexible con-
nection point adjacent the connection of the coupling
40 to the rotor 10 as defined by the flexible link 44A
25 between the rigid shaft 46 and the collar 42A. Simi-
larly, the connection point "d" is defined at the
flexible connection point adjacent to the connection
of the coupling 40 to the drive spindle 32 defined by
the flexible link 44B which extends between the rigid
30 shaft 46 and the collar 42B.

As noted earlier, the rotor's critical speed is
that rotational speed at which two events simultane-
ously occur. These events are, firstly, the parallel
alignment of the principal axis of the rotor (an axis
35 extending through the rotor center of gravity CG) and

the spin axis of the rotor (that is, an axis through
the geometric center of the rotor). Secondly, the
rotor's center of gravity CG must lie on the spin
axis. By making the satisfaction of these two con-
5 ditions independent of each other it is possible to
permit the rotor to attain its critical speed at a
lower rotational speed. As a consequence vibratory
forces imposed on the rotor by a given rotor unbalance
are lessened. Thus, the rotor may be enabled to
10 tolerate larger amounts of rotor unbalance.

The suspension system 12 in accordance with the
present invention isolates and makes independent the
satisfaction of the above two conditions imposed on a
rotor enabling it to reach its critical speed. The
15 suspension system 12 acts generally as a kinematic
equivalent of an infinite pendulum. As seen in the
force diagram of Figure 2, in order that the above two
conditions be independently achieved, the angle Θ_d
must at all times be made to equal the angle Θ_r.

20 In accordance with this invention the distance A
is defined by the following relationship:

$$A = \frac{L \bullet K_r}{K_r + K_d + L \bullet W} \qquad (1)$$

25
where

K_r is the torsional stiffness at the flexible
connection of the coupling to the rotor at
the connection point "r";

30 K_d is the torsional stiffness at the flexible
connection of the coupling to the rotor drive
at the connection point "d";

A is the distance that the center of gravity of
the rotor lies from the connection point "r";

35 L is the length of the rigid shaft; and

W is the weight of the rotor.

Utilizing the suspension system of the present
invention, as noted earlier, provides the kinematic
equivalent of an infinite pendulum. Thus, the appli-
cation of a force to the rotor acting through its
5 center of gravity will result only in the deflection
of the rotor. Simultaneously, a restoring couple
imposed upon rotor will result only in the tilting of
the rotor. In this way, the rotor's critical speed
becomes a function only of the torsional stiffnesses
10 of the couplings, the weight of the rotor, and the
length of the shaft.

15   .   Those skilled in the art having the benefit of
the present teachings may effect numerous modifica- .
tions thereto. These modifications are, however, to
be construed as lying within the scope of the present
invention as defined by the appended claims.

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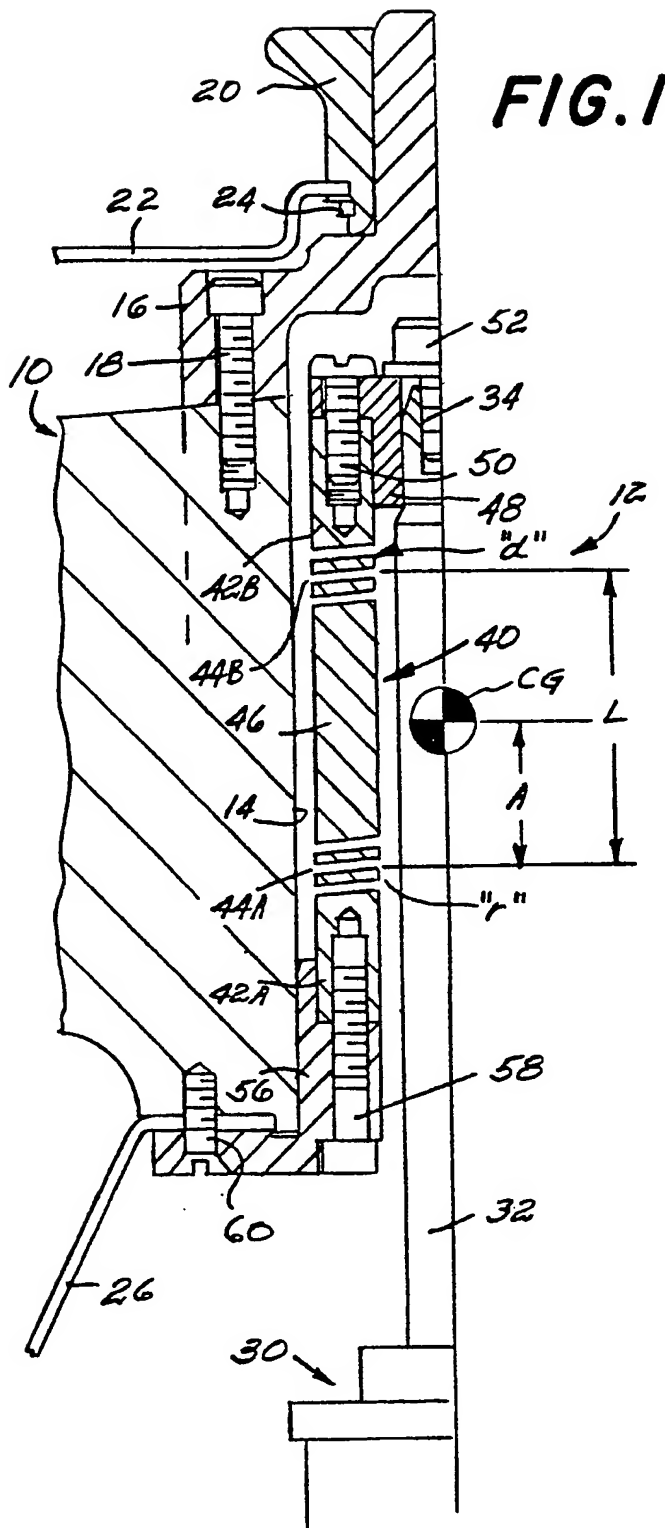
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WHAT IS CLAIMED IS:

1. In a centrifuge having a rotor with a
weight W and a drive member connectable to the rotor
the improvement comprising a suspension system for
5   mounting the rotor to the drive member, the suspension
system comprising a coupling having a first and a
second collar each connected by a flexible link to a
rigid shaft, one collar being connected at a connec-
tion point "r" to the rotor such that the rotor's
10   center of gravity lies a predetermined distance A
above the connection point "r" and the second collar
being connected at a second connection point "d" to
the shaft, the rigid shaft having a length L, the
flexible link adjacent the connection point "r" having
15   a torsional stiffness K_r associated therewith while
the flexible link adjacent the connection point "d"
having a torsional stiffness K_d associated therewith,
the distance A being defined by the relationship:

20
$$A = \frac{L \bullet K_r}{K_r + K_d + L \bullet W}$$

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30

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FIG.1

20
22
24
16
18
10
52
34
50
48
"d"
12
42B
44B
40
CG
46
L
14
A
44A
"r"
42A
56
58
60
32
26
30

FIG.2

Kd
"d"
θd
46
CG
32
A
L
θr
"r"
Kr